

Pomeron intercept from BFKL gluon dynamics in deep inelastic charm production at HERA

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In the framework of semihard (k_T factorization) QCD approach, we consider the differential cross sections of $D^{*\pm}$ meson production at HERA. The consideration is based on BFKL and CCFM gluon distributions. We find that in the case of BFKL LO gluon distribution the theoretical results are sensitive to the Pomeron intercept parameter Δ . We present a comparison of the theoretical results with available ZEUS experimental data.

1. INTRODUCTION

The experimental results on deep inelastic charm production obtained by the H1 [1] and ZEUS [2,3] Collaborations at HERA provide a strong impetus for further theoretical studies. This process is truly semihard because of the presence of two large scales: the virtuality of the exchanged photon (Q^2) and the charm mass (m_c^2), both being much larger than Λ_{QCD} but much smaller than s . Therefore, in the present note, we focus on the semihard approach [4,5] (SHA), which we had applied earlier to the $D^{*\pm}$ meson photoproduction [6,7] in a similar manner.

2. THE SEMIHARD APPROACH

It is known that the resummation [4,5,8,9] of the terms $[\ln(\mu^2/\Lambda^2)\alpha_s]^n$, $[\ln(1/x)\alpha_s]^n$ and $[\ln(\mu^2/\Lambda^2)\ln(1/x)\alpha_s]^n$ in SHA results in the so called unintegrated gluon distribution $\mathcal{F}(x, k_T^2, Q_0^2)$, which determines the probability to find a gluon carrying the longitudinal momentum fraction x and transverse momentum k_T at the probing scale Q_0^2 . It obeys the BFKL equation [10] and reduces to the conventional gluon

density $G(x, \mu^2)$ once the q_T dependence is integrated out:

$$\int_0^{\mu^2} \mathcal{F}(x, k_T^2, Q_0^2) dk_T^2 = x G(x, \mu^2). \quad (1)$$

The factorization scale Q_0^2 (such that $\alpha_s(Q_0^2) < 1$) indicates the scale of the nonperturbative input distribution.

The CCFM evolution equation [11] includes coherence effects via parton angular ordering and reproduces the BFKL evolution equation in the small x limit. Therefore the CCFM unintegrated parton distribution $\mathcal{A}(x, k_T^2, Q_0^2, \bar{q}^2)$ (unlike the function $\mathcal{F}(x, k_T^2, Q_0^2)$) depends also on the maximum angle allowed for any emission corresponding to $\bar{q} = \vec{p}_t/(1-z)$. In the small x limit it reduces to \mathcal{F} [11].

When calculating the spin average of the matrix element squared, we substitute the full lepton tensor for the photon polarization matrix:

$$\overline{\epsilon_\gamma^\mu \epsilon_\gamma^{*\nu}} = [8p_e^\mu p_e^\nu - 4(p_e q)g^{\mu\nu}]/(q^2)^2 \quad (2)$$

(including also the photon propagator factor). The virtual gluon polarization matrix is taken in

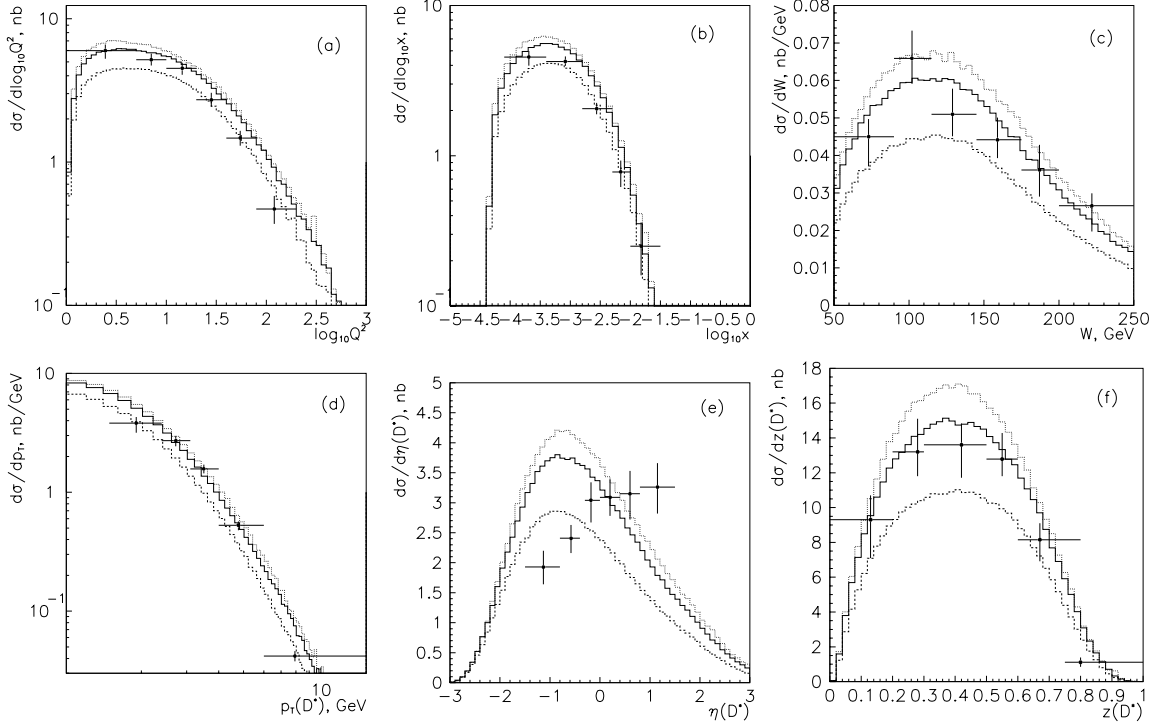


Figure 1. Differential cross sections for deep inelastic $D^{*\pm}$ production in the ZEUS accessible kinematical region as functions of: (a) $\log_{10} Q^2$, (b) $\log_{10} x$, (c) W , (d) $p_T(D^*)$, (e) $\eta(D^*)$ and (f) $z(D^*)$.

the form [4]:

$$\overline{\epsilon_g^\mu \epsilon_g^{*\nu}} = p_p^\mu p_p^\nu x^2 / |k_T|^2 = k_T^\mu k_T^\nu / |k_T|^2, \quad (3)$$

where p_e and p_p are the 4-momenta of the incoming electron and proton.

To parametrise the unintegrated structure functions, we use the prescriptions of ref. [12]. The proposed method lies upon a straightforward perturbative solution of the BFKL equation where the collinear gluon density $xG(x, \mu^2)$ is used as the boundary condition in the integral form (1). Technically, the unintegrated gluon density is calculated as a convolution of the collinear gluon density with universal weight factors:

$$\mathcal{F}(x, k_t^2, \mu^2) = \int_x^1 \mathcal{G}(\eta, k_t^2, \mu^2) \frac{x}{\eta} G\left(\frac{x}{\eta}, \mu^2\right) d\eta, \quad (4)$$

$$\mathcal{G}(\eta, k_t^2, \mu^2) = \frac{\bar{\alpha}_s}{\eta k_t^2} J_0(2\sqrt{\bar{\alpha}_s \ln(1/\eta) \ln(\mu^2/k_t^2)}), \quad k_t^2 < \mu^2, \quad (5)$$

$$\mathcal{G}(\eta, k_t^2, \mu^2) = \frac{\bar{\alpha}_s}{\eta k_t^2} I_0(2\sqrt{\bar{\alpha}_s \ln(1/\eta) \ln(k_t^2/\mu^2)}), \quad k_t^2 > \mu^2, \quad (6)$$

where J_0 and I_0 stand for Bessel functions (of real and imaginary arguments, respectively), and $\bar{\alpha}_s = \alpha_s/3\pi$. The latter parameter is connected with the Pomeron trajectory intercept: $\Delta = \bar{\alpha}_s 4 \ln 2$ in the LO, and $\Delta = \bar{\alpha}_s 4 \ln 2 - N \bar{\alpha}_s^2$ in the NLO approximations, respectively, where $N \sim 18$ [13].

In the previous work [6] we used the standard GRV parametrization [14] for the collinear gluon density, from which the unintegrated gluon distribution was developed according to eqs. (4) - (6).

Some other essential parameters were chosen as follows: the charm quark mass $m_c = 1.5$ GeV, the Peterson fragmentation parameter $\epsilon = 0.06$, the overall $c \rightarrow D^*$ fragmentation probability 0.26. The Pomeron intercept Δ was regarded as free parameter, and then the value $\Delta = 0.35$ has been extracted from a fit to the experimental $p_T(D^*)$ spectrum measured by the ZEUS collaboration [15].

In this paper we also use an unintegrated gluon density coming from a solution of the CCFM evolution equation (see [16]). It was shown in [16] that a good description of the inclusive structure function $F_2(x, Q^2)$ and the production of forward jets in DIS, which are believed to be a prominent signature of small x parton dynamics, can be obtained using the CCFM unintegrated gluon distribution. In [7] we have used the hadron level Monte Carlo program CASCADE described in [16] to predict the cross section for D^* photoproduction at HERA energies. It was shown that in this case the description of the differential cross section $d\sigma/d\eta(D^*)$ for $Q^2 < 1$ GeV² for different regions of $p_T(D^*)$ is improved.

3. NUMERICAL RESULTS

The theoretical predictions on the differential cross sections of deep inelastic D^* production are shown in Figure 1 for the ZEUS kinematical region: $1 < Q^2 < 600$ GeV², $1.5 < p_T(D^{*\pm}) < 15$ GeV and $\eta(D^{*\pm}) < 1.5$. Different curves in Figure 1 correspond to different values of the Pomeron intercept parameter: $\Delta = 0.166$ (dotted), 0.35 (solid) and 0.53 (dashed). We see that the theoretical curves with $\Delta = 0.35$ describe all ZEUS experimental data [3] on the differential cross sections, except the $d\sigma/d\eta(D^*)$ distribution. The SHA calculations with BFKL unintegrated gluon distribution show some shift to negative $\eta(D^*)$ with respect to the data. This discrepancy between the data and the SHA prediction could result from the use of the Peterson fragmentation function. Another reason may be connected with the BFKL LO unintegrated gluon density.

The use of CCFM unintegrated gluon den-

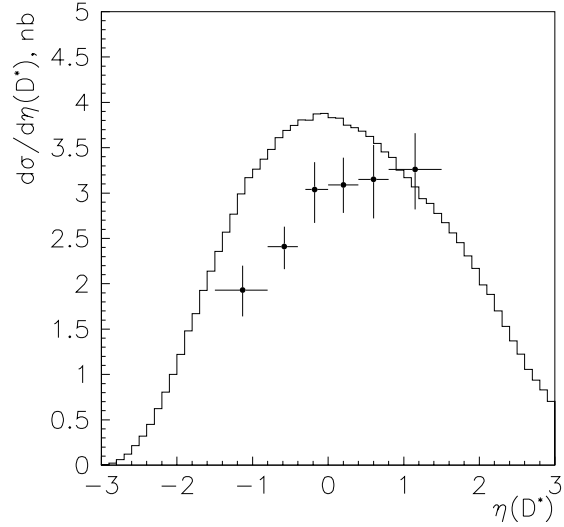


Figure 2. $d\sigma/d\eta(D^*)$, CCFM scheme with Peterson fragmentation.

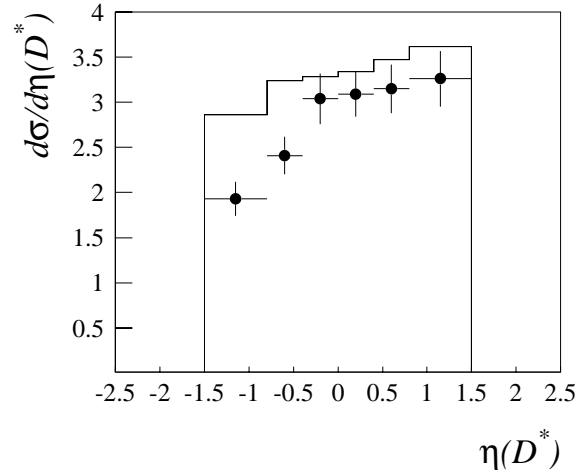


Figure 3. $d\sigma/d\eta(D^*)$, CCFM scheme with JET-SET fragmentation.

sity (with angular ordering) from MC generator CASCADE [16] with the Peterson fragmentation function for $c \rightarrow D^{*+}$ transition gives some positive shift to the $d\sigma/d\eta(D^*)$ distribution (Figure 2) compared to BFKL curve (see Figure 1e). Finally, when we use the CCFM unintegrated gluon distribution with more realistic JETSET based fragmentation function [17] implemented in [16] we obtain good agreement between our theoretical results and the ZEUS experimental data [3] for $d\sigma/d\eta(D^*)$ (Figure 3).

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